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Natural Production Potential of Some Rio Puerco Soils in New Mexico[1]

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Soils from six representative plant communities on the upper Rio Puerco Watershed in New Mexico were sampled and tested for inherent production capability. Tests included leaf area and dry weight of greenhouse grown barley (*Hordium vulgare* var. Arivat), soil chemical/physical properties, dehydrogenase activity, and plant community herbaceous production. There was no difference between inherent production capability of the soils based on barley leaf area and dry weight; barley leaf area was correlated to soil chemical properties and herbaceous production was correlated with plant communities.

Keywords: soil capability, dehydrogenase, bioassay, Rio Puerco, New Mexico.

Quantification and description of plant communities provides a way to categorize land units having similar environments and biotic potentials, and which can be expected to respond similarly to disturbance. This note examines natural productivity of some soils which were identified on the Rio Puerco watershed (Francis 1986). The soil and climatic characteristics of these plant communities will determine their natural productivity. Management practices have altered these conditions, and can be used to improve future productivity.

Study Area and Methods

The Upper Rio Puerco Watershed, in northwestern New Mexico, was classified into 45 ecological phyto-edaphic communities using cluster analysis based on species importance values (Francis 1986). The combination of landform, vegetation and soil was used to classify phyto-edaphic communities.

A review of the 45 communities on the Rio Puerco watershed showed six plant communities occurring most frequently.

Plant community number	Name	% of total
6	*Juniperus monosperma/ Gutierrezia sarothrae/ Bouteloua gracilis-Hilaria jamesii* (Jumo/Gusa/Bogr-Hija)	11
9	*Artemisia tridentata/ Bouteloua gracilis-Hilaria jamesii* (Artr/Bogr-Hija)	5
13	*Artemisia tridentata-Gutierrezia sarothrae/ Bouteloua gracilis-Agropyron smithii* (Artr-Gusa/Bogr-Agsm)	16
18	*Chrysothamnus nauseosus* spp. *bigelovii/Bouteloua gracilis-Agropyron smithii* (Chnab/Bogr-Agsm)	7
32	*Gutierrezia sarothrae/ Bouteloua gracilis-Hilaria jamesii* (Gusa/Bogr-Hija)	8
42	*Gutierrezia sarothrae/ Sporobolus airoides-Hilaria jamesii* (Gusa/Spai-Hija)	6
	Total	53%

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Each plant community contained from three to twenty-one 180-m Community Structural Analysis (CSA) transects installed in 1979. The CSA technique includes measurement for litter, bare soil, diversity and, by plant species, foliar cover, density, frequency, and Importance Values (Pase 1981). Each transect was given a community description based on 7 years of data collection (Francis 1986). Also, at each transect and to the side, herbaceous production measurements were taken for each study year (Schumacher and Chapman 1948).

Because each plant community (PC) was found on several soil series, only transects that contained medium-textured soils were selected, to minimize variability in this study. These textures consisted of sandy loam, loam, sandy clay loam, and clay loam. At each of the selected transects (5 transects per plant community), three soil subsamples were collected randomly along the length of the transect line to a depth of 15 cm, using a 5 cm (diameter) bucket auger. The three subsamples were mixed thoroughly in a sterile plastic bag, and were cooled immediately in an ice-chest. At the laboratory, the samples were passed through a 2-mm sieve and were stored at 4°C. An aliquot from each sample was taken for laboratory analyses at the New Mexico State University Soil and Water Testing Laboratory. The soluble cations were determined by atomic absorption. Available phosphorus was determined by Olson's procedure using $NaHCO_3$; NH_4 -N was determined colorimetrically (from a 1:5 soil/KC1 extract), and NO_3 -N was determined by Cd reduction (from a 1:5 soil/water extract). Total nitrogen was determined by the micro-Kjeldahl procedure (TKN). Organic matter was determined by the Walkley-Black procedure (Allison 1965) and the hydrometer method was used to determine texture (USDA 1972).

In addition to the standard soil analysis conducted on each transect, additional sampling was done. Using methods previously described, soil samples were collected along the same transects and were taken to the laboratory to estimate biological activity in the soils as measured by the dehydrogenase method (Skujins 1973), and for a productivity study using barley. Dehydrogenase is a general indicator of microbial activity, and barley plants are commonly used in bio-assay tests of agronomic soil fertility (Campbell 1968).

The cumulative effects of the soil properties enhancing plant growth are readily visible using barley plants under controlled conditions. In such studies, climate, soil texture, and moisture conditions are constant, in contrast to wide variations of these variables under field conditions.

In this study, barley plants were used as indicators of plant response to unamended soil fertility under optimum moisture conditions. Ninety, 3.8-L plastic nursery pots were lined with paper toweling to retain the soil and were filled with soil from each transect. There were three replications of each soil (e.g., medium textured soils = 3 reps × 6 plant communities × 5 transects = 90 pots).

Ten barley seeds were planted 6 mm deep in each pot and were thinned to 5 seedlings after 10 days. Pots were watered with 1,200-mL of distilled water initially and 100-mL of distilled water every other day, to maintain optimum moisture conditions for the 37 days of the study. The greenhouse temperatures were kept at 27° C day and 19° C night. No artificial light was used during October and November.

The barley plants were harvested after 37 days and immediately were placed under a leaf area meter and a composite of leaf area derived for the five plants in each pot. Plant samples then were oven dried for 48 hours at 70°C, were weighed and sent to New Mexico State University Plant and Soils Lab for nutrient analysis (percent P, K, Ca, Na, and ppm of Fe; samples were too small for TKN analysis). The three replicate pots were averaged to obtain response measurements for each transect.

A series of analyses was used to determine if the soils from the six plant communities selected had inherently different natural production capabilities. Analysis of "productive capability" took different forms.

To evaluate barley response to soil conditions (and, therefore, suitability as indicator of fertility or potential productivity) barley leaf area and dry weight were compared to the soil measurements.

Barley leaf area and field estimates of production, cover, density, and dehydrogenase activity were compared among plant communities using one-factor analysis of variance. Significant overall tests of variation among soils were followed using least significant difference analysis of pairwise differences between plant communities.

Results and Discussion

Because this analysis included only medium-textured soils, there were no significant differences in textures among the soils representing each of the plant communities (table 1). In contrast, each plant community had at least one or more chemical properties that were significantly different from each other (table 1). For example, soil from plant community 42 had significantly higher Na and SAR values compared to the soils from most of the other plant communities. Soil P, NO_3 -N, and TKN was significantly higher in plant community 13 compared to one or two of the other plant communities. Organic matter contents ranged from a low of 0.61% in the soil from plant community 32 to a significantly higher 1.15% in the soil from plant community 9. Soil from plant community 13 had a significantly lower pH value than all the other communities.

Barley leaf area was only moderately correlated to soil properties, based on correlation analysis when all communities were combined. Positive correlations between leaf area and organic matter, P, K, and total N were observed (table 2). Other properties, such as EC and SAR, had negative correlations; but none were significant.

When barley leaf area was compared between soils of the plant communities, none were significantly different. If, as indicated above, barley is a reasonable indicator of soil fertility, then the plant communities were not closely related to soil fertility usually encountered in agricultural systems.

Table 1.—Chemical and physical properties associated with soils from six semi-arid plant communities.

Plant community	Soluble cations				Phosphorus and nitrogen				Organic matter	pH	EC	SAR	Sand	Silt	Clay
	Na	Ca	Mg	K	P	NH_4-N	NO_3-N	TKN							
	-------- meq L^{-1} --------				---------- ppm ----------				%		dSm^{-1}		-------- % --------		
6 Jumo/Gusa/ Bogr-Hija	0.81b[1]	2.77ab	0.93	0.43ab	2.0c	2.49	1.82ab	625ab	0.95ab	7.66a	0.48ab	0.71b	53	23	25
9 Artr/Bogr-Hija	0.57b	3.65ab	0.71	0.27ab	5.0ab	3.26	2.20ab	620ab	1.15a	7.50a	0.48ab	0.40b	56	19	25
13 Artr-Gusa/ Bogr-Agsm	1.98b	1.62b	0.43	0.13b	5.1a	3.80	4.06a	807a	1.05ab	7.04b	0.40b	2.51b	51	23	26
18 Chnab/Bogr- Agsm	1.05b	2.84ab	0.91	0.64a	2.7abc	3.74	2.84ab	756a	0.96ab	7.67a	0.50ab	0.78b	53	22	25
32 Gusa/Bogr-Hija	0.75b	3.85ab	0.94	0.36ab	2.2bc	1.96	1.24b	700a	0.61b	7.83a	0.53ab	0.51b	52	25	23
42 Gusa/Spai-Hija	7.09a	8.63a	0.86	0.37ab	2.7abc	2.57	2.20ab	462b	0.65ab	7.70a	1.41a	7.62a	47	25	28

[1]*Means within the same column followed by the same letter are not significantly different at the 0.05 level according to the F-protected Least Significant Difference (L.S.D.) test.*

Table 2.—Pearson's correlation coefficients for barley leaf area and abiotic variables associated with soils from six plant communities.

Soil properties	Correlation coefficients
Organic matter	0.38*
P	0.41*
K	0.40*
TKN	0.57*
EC	-0.23
SAR	-0.07
pH	-0.18
Na	-0.16
Ca	-0.25
Mg	-0.25
NO_3-N	-0.01
NH_4-N	0.14
Sand	-0.27
Silt	0.33
Clay	-0.00

**Significant at 5% significance level.*

Table 3.—Average annual forage production (all years) by plant communities.

Plant community	Mean forage lb/ac	Std. dev.	
6 Jumo/Gusa/Bogr-Hija	396.4	54.6	a[1]
18 Chnab/Bogr-Agsm	340.9	42.2	b
32 Gusa/Bogr-Hija	335.7	37.2	b
42 Gusa/Spai-Hija	311.6	28.6	b
9 Artr/Bogr-Hija	250.6	43.5	c
13 Artr-Gusa/Bogr-Agsm	171.5	33.8	d

[1]*Different letters in the column indicate significant differences at the 0.05 level according to the F- protected L.S.D. test.*

Table 4.—Plant communities vs. average transect cover values (all years).

Plant community	Mean cover %	Std. dev.	
6 Jumo/Gusa/Bogr-Hija	33.3	9.5	ab[1]
9 Artr/Bogr-Hija	32.5	7.5	abc
13 Artr-Gusa/Bogr-Agsm	29.2	7.3	bc
18 Chnab/Bogr-Agsm	40.4	10.6	a
32 Gusa/Bogr-Hija	29.5	5.0	bc
42 Gusa/Spai-Hija	24.5	6.6	c

[1]*Different letters in the column indicate significant differences at the 0.05 level according to the F- protected L.S.D. test.*

Table 5.—Plant communities vs. transect density values (all years).

Plant community	Mean density plants/0.5 m^2	Std. dev.	
18 Chnab/Bogr-Agsm	83.9	26.7	a[1]
32 Gusa/Bogr-Hija	65.2	23.1	ab
13 Artr-Gusa/Bogr-Agsm	59.9	25.3	b
6 Jumo/Gusa/Bogr-Hija	56.9	20.5	b
9 Artr/Bogr-Hija	47.9	26.6	b
42 Gusa/Spai-Hija	39.4	10.4	c

[1]*Different letters in the columns indicate significant differences at the 0.05 level according to the F- protected L.S.D. test.*

Table 6.—Dehydrogenase activity associated with soils from six semi-arid plant communities.

Plant community	Dehydrogenase activity
	μg Formazan g^{-1} d^{-1}
32 Gusa/Bogr-Hija	23 a[1]
6 Jumo/Gusa/Bogr-Hija	18 ab
42 Gusa/Spai-Hija	17 b
18 Chnab/Bogr-Agsm	15 b
9 Artr/Bogr-Hija	15 b
13 Artr-Gusa/Bogr-Agsm	12 b

[1]*Means within the same column followed by the same letter are not significantly different at the 0.05 level according to the F- protected Least Significant Difference (L.S.D.) test.*

An analysis of the herbaceous production data for 1985 among plant communities showed significant differences in three communities (communities 6, 9, and 13). These preliminary results suggested that further analysis using production for all years was worth testing against plant communities. For example, when the average of all years of herbage production from transect data was tested among plant communities, significant differences among plant communities were apparent (table 3). Plant community 6 was significantly higher in herbage production than the other plant communities, with 18 second; 32, 42, and 9 the same; and 13 the poorest producer (table 3).

A test of plant communities vs. percent cover as measured on the transects for the average of all years showed that plant community 18 was significantly different from 42, 32, and 13, and 6 significantly different than 42 (table 4).

A test of plant communities vs. plant density, as measured on the transects for the average of all years, showed that plant community 18 was significantly different from 42, 9, 13, and 6, and 42, different from the rest (table 5).

Dehydrogenase activity ranged from 12 to 23 μg formazan g^{-1} d^{-1} in the soil (table 6). Soil from plant community 32 was significantly higher in dehydrogenase activity compared to four of the other plant communities. Soil from plant community 13 had the lowest dehydrogenase activity, which correlates well with the lower plant production values obtained from the field transect data.

Conclusions

Field measurements of productivity vary among plant communities. Herbaceous production, foliar cover, and density values of Jumo/Gusa/Bogr-Hija (6) and Chnab/Bogr-Agsm (18) plant communities were the most productive communities evaluated. Herbage production averaged between 340 and 400 lb/A. The Gusa/Spai-Hija (42) and Artr-Gusa/Bogr-Hija (13) plant communities have much less production and also low cover and density values.

Neither leaf area nor dry weight of barley was able to differentiate differences in inherent productivity among these unamended soils from these six plant communities. The barley tests showed that, under optimum moisture condition, inherent productivity does not vary among the soils of the selected plant communities.

The next steps in the research process are to identify possible causes for field variation in productivity.

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